ARIZONA DEPARTMENT OF TRANSPORTATION

REPORT NUMBER: AZ-SP-9303

# CONSTRUCTION REPORT FOR CRASH CUSHION ATTENUATING TERMINAL

## Special Report

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**June 1993**

**Prepared for:**
Arizona Department of Transportation
206 South 17th Avenue
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in cooperation with
U.S. Department of Transportation
Federal Highway Administration

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16. Abstract

The Crash Cushion Attenuating Terminal (CAT), is a proprietary system manufactured by SYRO Steel Company. It is designed to be an end treatment for a guardrail and a crash cushion for head-on impacts. As an end treatment for guardrail, it is designed to provide a crash worthy means of terminating a guardrail. As a crash cushion it is designed to prevent errant vehicles from impacting hazards by either smoothly decelerating the vehicle to a stop when hit head-on, or by redirecting it away from the hazard for glancing impacts.

The FHWA upgraded the classification of the CAT system to that of an operational barrier in 1990. However, due to the dearth of field performance data, the FHWA encouraged the states to continue installing and monitoring the CAT system as an experimental barrier in order to learn more about the performance of the system.

The objective of this project was to evaluate the in-service performance of the CAT system according to the recommendations as provided in the NCHRP Report 230. Five CAT systems were installed as part of construction project RAM-600-0-501 on Sky Harbor Boulevard in Phoenix, Arizona. Sky Harbor Boulevard is part of the ground access street system to the Phoenix Sky Harbor International Airport. Five G Inc. installed the CAT systems between 10/19/91 and 3/14/92. Each CAT system installed in this project was 57 ft. 11.75 in. long, and consisted of a 26 ft. 8.75 in. tail end transition to a concrete barrier wall and a 31 ft. 3 in. CAT subsystem. The CAT systems were installed at predetermined sites based on a construction change order that called for substituting the CAT systems for the G.R.E.A.T systems which were in the initial contract drawings for the project.

On the basis of the installation and inspection procedures that were followed, it was concluded that the five CAT systems were installed according to the manufacturer's specifications. Therefore, it was recommended that the CAT system evaluation process proceed as planned. In order to obtain a better estimate of the initial cost of the CAT system, it was recommended that future CAT systems be included in the initial design document as bid items instead of as change-order items as was the case in this project.

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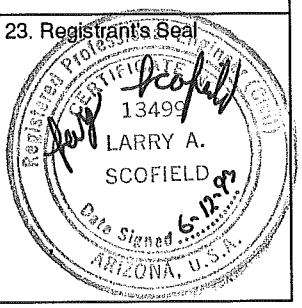
| Crash Cushion, Guard Rail, Highway Appurtenance, Roadside Features, Attenuating Terminal, CAT. | Document is available to the U. S. Public through the National Technical Information Service, Springfield, Virginia 22161 |  |



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# SI* (MODERN METRIC) CONVERSION FACTORS

## APPROXIMATE CONVERSIONS TO SI UNITS

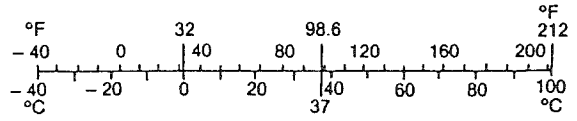
| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| **LENGTH** | | | | |
| in | inches | 25.4 | millimetres | mm |
| ft | feet | 0.305 | metres | m |
| yd | yards | 0.914 | metres | m |
| mi | miles | 1.61 | kilometres | km |
| **AREA** | | | | |
| $in^2$ | square inches | 645.2 | millimetres squared | $mm^2$ |
| $ft^2$ | square feet | 0.093 | metres squared | $m^2$ |
| $yd^2$ | square yards | 0.836 | metres squared | $m^2$ |
| ac | acres | 0.405 | hectares | ha |
| $mi^2$ | square miles | 2.59 | kilometres squared | $km^2$ |
| **VOLUME** | | | | |
| fl oz | fluid ounces | 29.57 | millilitres | mL |
| gal | gallons | 3.785 | litres | L |
| $ft^3$ | cubic feet | 0.028 | metres cubed | $m^3$ |
| $yd^3$ | cubic yards | 0.765 | metres cubed | $m^3$ |

NOTE: Volumes greater than 1000 L shall be shown in $m^3$.

| | | | | |
|---|---|---|---|---|
| **MASS** | | | | |
| oz | ounces | 28.35 | grams | g |
| lb | pounds | 0.454 | kilograms | kg |
| T | short tons (2000 lb) | 0.907 | megagrams | Mg |
| **TEMPERATURE (exact)** | | | | |
| °F | Fahrenheit temperature | 5(F-32)/9 | Celcius temperature | °C |

## APPROXIMATE CONVERSIONS FROM SI UNITS

| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| **LENGTH** | | | | |
| mm | millimetres | 0.039 | inches | in |
| m | metres | 3.28 | feet | ft |
| m | metres | 1.09 | yards | yd |
| km | kilometres | 0.621 | miles | mi |
| **AREA** | | | | |
| $mm^2$ | millimetres squared | 0.0016 | square inches | $in^2$ |
| $m^2$ | metres squared | 10.764 | square feet | $ft^2$ |
| ha | hectares | 2.47 | acres | ac |
| $km^2$ | kilometres squared | 0.386 | square miles | $mi^2$ |
| **VOLUME** | | | | |
| mL | millilitres | 0.034 | fluid ounces | fl oz |
| L | litres | 0.264 | gallons | gal |
| $m^3$ | metres cubed | 35.315 | cubic feet | $ft^3$ |
| $m^3$ | metres cubed | 1.308 | cubic yards | $yd^3$ |
| **MASS** | | | | |
| g | grams | 0.035 | ounces | oz |
| kg | kilograms | 2.205 | pounds | lb |
| Mg | megagrams | 1.102 | short tons (2000 lb) | T |
| **TEMPERATURE (exact)** | | | | |
| °C | Celcius temperature | 1.8C + 32 | Fahrenheit temperature | °F |




* SI is the symbol for the International System of Measurement

(Revised April 1989)

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# CONSTRUCTION REPORT FOR CRASH CUSHION ATTENUATING TERMINAL

## INTRODUCTION

### ADOT Standard End Treatments

The Arizona Department of Transportation (ADOT) commonly uses the Breakaway Cable Terminal (BCT) and the Standard Attenuator Assembly for rigid roadside hazards[1]. The BCT is a guardrail end treatment with an anchored cable designed to redirect a vehicle upon lateral impact. The Standard Attenuator Assembly incorporates BCT features and also provides additional attenuating protection for head-on collisions.

### Traffic Barrier Performance Criteria

ADOT has continued to observe the safety performance criteria of longitudinal traffic barriers and other highway appurtenances as presented in the National Cooperative Highway Research Program Report Number 230 (NCHRP-230)[2]. The report states that although the safety performance cannot be measured directly, it can be judged on the basis of structural adequacy, occupant risk, and vehicle trajectory after collision. To satisfy the NCHRP-230 performance requirement, a traffic barrier ought to either stop or redirect an errant vehicle while maintaining the following performance goals:

- Detached elements, fragments, or other debris from the appurtenance must not penetrate the passenger compartment of the impacting vehicle or present undue hazard to other traffic.
- The vehicle should remain upright and decelerate in such a manner as to avoid occupant injury.
- After collision, the vehicle trajectory and final stopping position should intrude a minimum distance, if at all, into adjacent or opposing traffic lanes.

### Acceptance Procedure for Barrier Performance

The FHWA classifies traffic barrier systems based on their stage of development as: (i) research and development, (ii) experimental, and (iii) operational. A research and development barrier is one for which there has not been sufficient crash tests or field evaluation. An experimental barrier system is one which has performed satisfactorily in crash tests, but for which necessary in-service field evaluations have not been completed. An operational barrier system is one which has performed satisfactorily in crash tests and during in-service field evaluation.

In-service field evaluations are conducted to determine how an appurtenance performs for a broad range of service parameters which cannot be easily simulated during crash tests. These conditions include: (i) unpredictable conditions of collision, (ii) environment, (iii) life cycle cost, and (iii) maintenance situation for a variety of site and traffic conditions.

### The CAT System

The Crash Cushion Attenuating Terminal (CAT), shown in Figure 1, is a proprietary system manufactured by SYRO Steel Company of Girard, Ohio. It is designed to be both an end treatment for a guardrail and a crash cushion for impacts from both directions. As an end treatment for guardrail, it is designed to provide a crash worthy means of terminating a guardrail. As a crash cushion it is designed to prevent errant vehicles from impacting hazards by either smoothly decelerating the vehicle to a stop when hit head-on, or by redirecting it away from the hazard for glancing impacts. The CAT consists of the following main components:

- Six wooden posts installed at 6' 3" spacing between centers;
- Steel tubes and soil plates which provide the post foundations;
- A nose section consisting of two side plates and a nose piece;
- A front anchor system which includes an anchor cable, a spacer channel and a channel strut;
- 12-GA slotted rails installed to span between posts #2 and #4;
- 10-GA slotted rails installed to span between posts #4 and #6; and
- The tail end which is a transition assembly between the CAT and the roadway hazard being protected. The tail end consists of steel posts and W-beams configured to provide the necessary interface to the hazard.

The FHWA upgraded the classification of the CAT system to that of an operational barrier in 1990. However, due to the dearth of field performance data, FHWA encouraged the states to continue installing and monitoring the CAT system as an experimental barrier in order to learn more about the performance of the system. Appendix A contains a reproduction of the 1990 letter from FHWA to SYRO Steel Company about the classification of the CAT system to an operational barrier.

### The CAT Kinetic Energy Absorption Concept

The initial impact of the vehicle forces the nose section of the terminal to buckle outward from the center. The buckled section becomes a buffer which is then pushed along with the guardrails to effect telescoping of the slotted sections. The small tabs of steel built into slots of the sections tear off during the telescoping action. During this process, the kinetic energy of the impacting vehicle is dissipated as work done to buckle the nose sections and work done to tear off the steel tabs built into the slots.

## OBJECTIVES

The objective of this project is to evaluate the in-service performance of the CAT system according to the recommendations as provided in the NCHRP-230 report. In-service evaluation is being conducted to identify system problems, if any, associated with construction procedures, operation, and maintenance of safety devices, under a variety of circumstances at typical sites. These problems may not have been evident during controlled crash tests. If any problems are discovered,

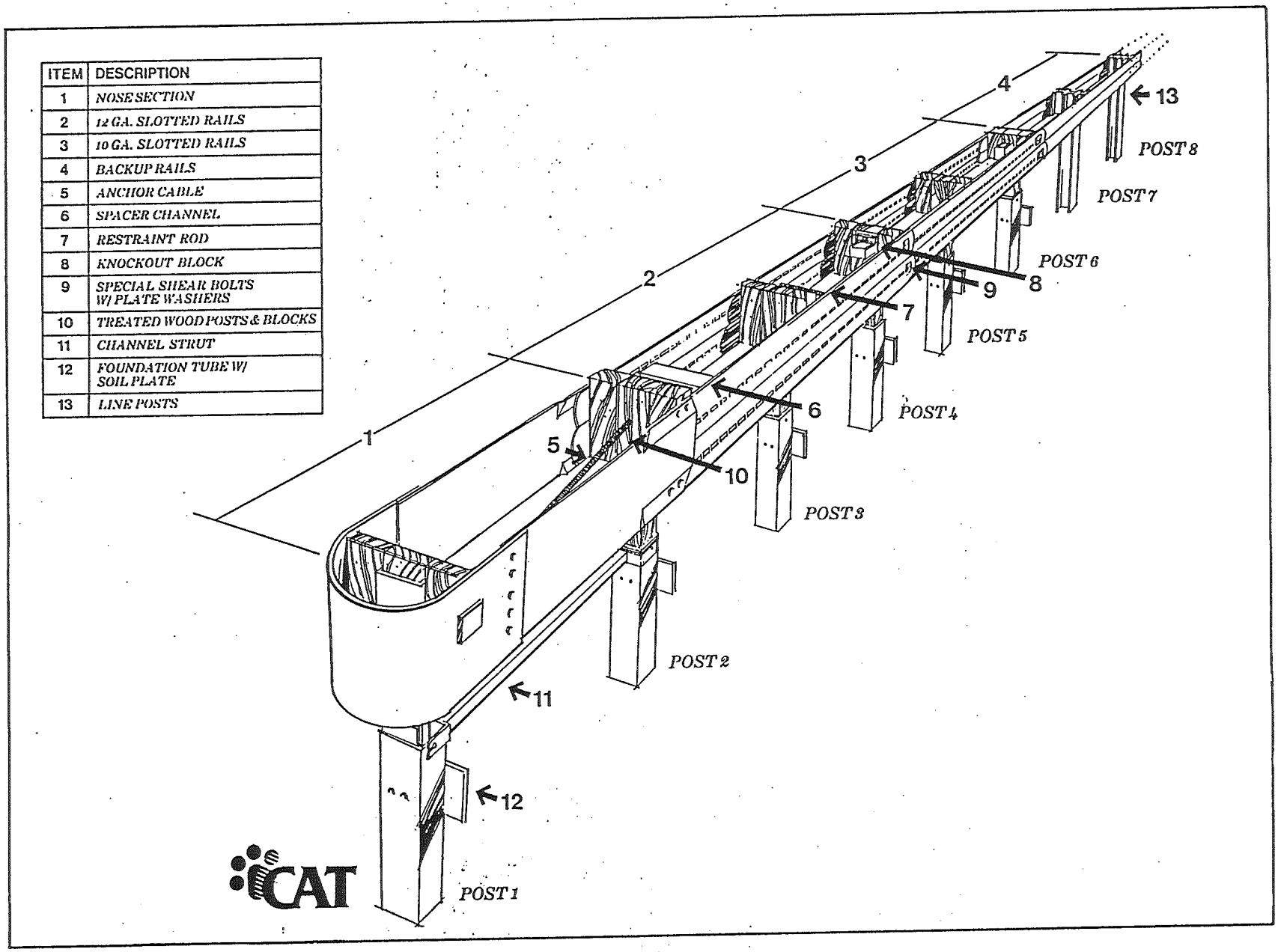



Figure 1: The Crash Cushion Attenuating Terminal (CAT)

appropriate recommendations will be given on how to deal with the device problems. The CAT system was installed and will be monitored in accordance with the FHWA approved workplan. Copies of the work plan, letter of transmission to FHWA, and the FHWA approval are shown in appendices B, C, and D, respectively.

## CONSTRUCTION

### Locations of Crash Cushion Attenuating Terminal Installations

The ADOT Advisory committee for Traffic and Safety New Product Evaluation met on June 28, 1991 and discussed the possible use of the CAT system. The committee decided during the meeting not to pursue any test sections. However, the committee recommended that an in-service field evaluation be conducted for the CAT systems that were being installed on sections of the Sky Harbor Boulevard in Phoenix, Arizona. The CAT systems were being installed instead of the G.R.E.A.T systems because the construction cost of the CAT systems would be 25 percent less.

Five CAT systems were installed on project RAM-600-0-501, on Sky Harbor Boulevard. The Sky Harbor Boulevard is part of the ground access to the Phoenix Sky Harbor International Airport. Five G Inc. of Phoenix, Arizona installed the CAT systems between 10/19/91 and 3/14/92. A summary of the actual locations, dates of installation and dates of opening to traffic are given in Table 1. Figure 2 shows a map of the approximate locations of the CAT installations.

**TABLE 1: LOCATIONS OF CAT INSTALLATIONS IN PROJECT RAM-601-0-501**

| CAT No. | Roadway Section | Side of Roadway | Station[a] | Protected Hazard | Date Installed | Date Opened to Traffic |
|---|---|---|---|---|---|---|
| 1 | Sky Harbor Blvd. West Bound (WB) | Right | 35+10 | Concrete Half Barrier | 10/20/91 | 10/21/91 |
| 2 | Sky Harbor Blvd. East Bound (EB) | Right | 24+51 | Concrete Half Barrier | 10/19/91 | 10/21/91 |
| 3 | Ramp EN[b] | Left | 11+70 | Concrete Half Barrier | 10/19/91 | 3/19/92 |
| 4 | Ramp EN[b] | Right | 20+31 | Concrete Half Barrier | 3/14/92 | 3/19/92 |
| 5 | Ramp SW[c] | Right | 47+04 | Concrete Half Barrier | 10/20/91 | 3/19/92 |

Notes: a. Station designates the interface of CAT and the protected hazard.
b. Ramp from Sky Harbor Blvd. (EB) into 44th St. North Bound (NB).
c. Ramp from 44th Street South Bound (SB) into Sky Harbor Blvd. (WB).
44th street abuts SR 153 at its north end; outside the borders of Figure 2.

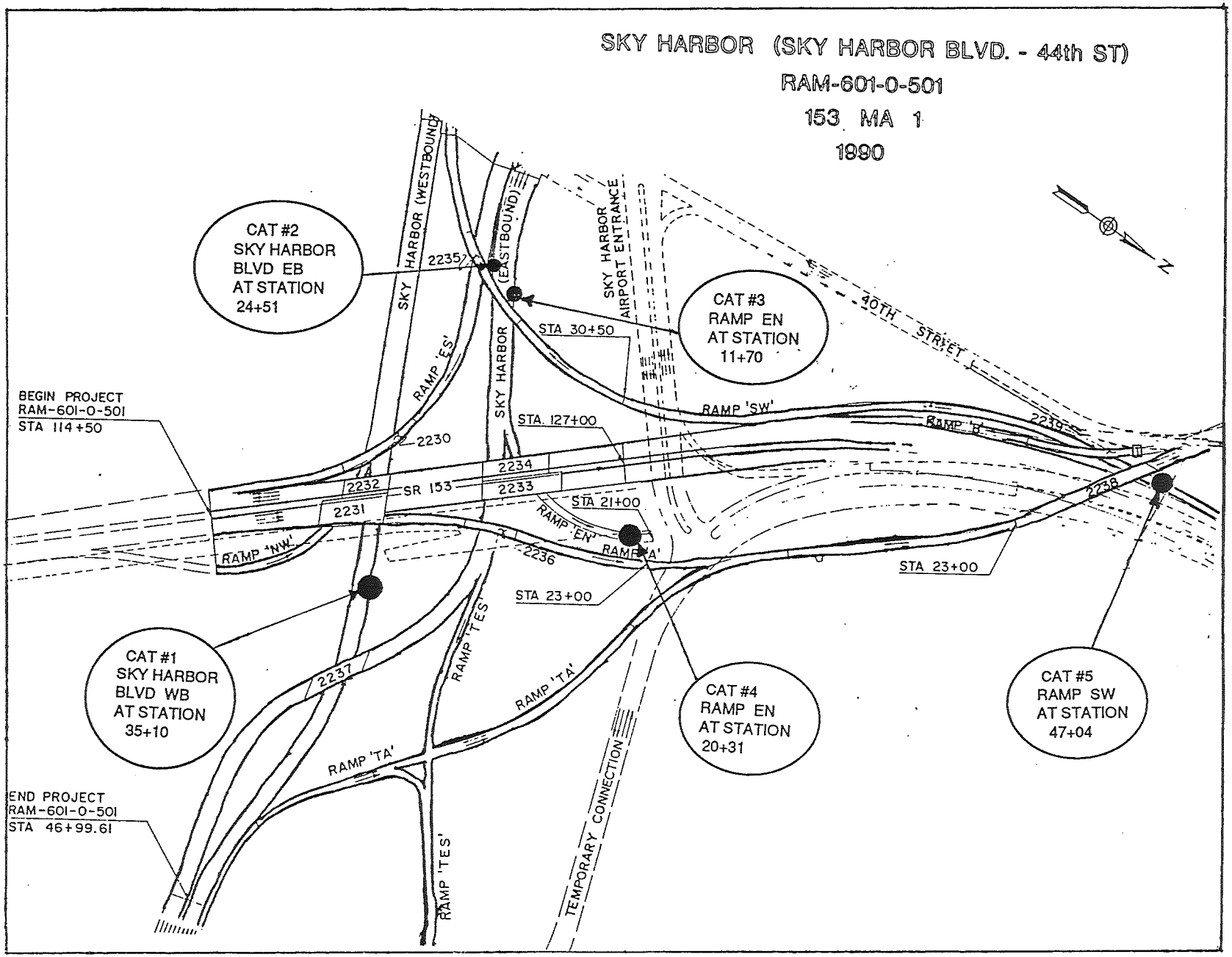



**Figure 2: Locations of Crash Cushion Attenuating Terminal Installations**

The decision to use the CAT system instead of the G.R.E.A.T system on the Sky Harbor Boulevard was made while the highway construction was in progress. The locations of the CAT systems were based on a project change order which called for the installation of CAT systems at locations initially designed for the G.R.E.A.T systems. For the purpose of the in-service performamce evaluation of these CAT systems, no other site selection criteria were considered.

### Highway and Traffic Characteristics

The main line sections of the highways consist of three 12-foot wide lanes in each direction. The highway and traffic characteristics near the CAT installations are summarized in Table 2. Two of the five CAT systems were installed within horizontal curves. One of the curves is on the mainline section of the Sky Harbor Boulevard and was designed for 40 mph traffic speed. The second curve, part of ramp EN, was designed for 30 mph traffic speed. The remaining three CAT systems were installed in sections designed for 50 mph traffic speed. The design traffic volumes for the year 2010 were estimated as summarized in Table 3.

**TABLE 2: HIGHWAY CHARACTERISTICS NEAR EACH CAT INSTALLATION**

| CAT Number | Roadway Section | Station | Approach[a] Grade (%) | Horizontal Curvature | Design speed (mph) |
|---|---|---|---|---|---|
| 1 | Sky Harbor Blvd. (WB) | 35+10 | -0.50 | tangent | 50 |
| 2 | Sky Harbor Blvd. (EB) | 24+51 | -0.70 | Radius = 954.93 ft | 40 |
| 3 | Ramp EN[b] | 11+70 | not given | tangent | 50 |
| 4 | Ramp EN[b] | 20+31 | +1.00 | Radius = 409.26 ft | 30 |
| 5 | Ramp SW[c] | 47+04 | -0.50 | tangent | 50 |

a. Approach grade with respect to travel direction
b. Ramp from Sky Harbor Blvd. (EB) into 44 St. (NB)
c. Ramp from 44 St. (SB) into Sky Harbor Blvd. (WB)

### Site Meteorology

The CAT systems have been installed in a desert climate site. The temperature and rainfall data for the site are based on the Phoenix Sky Harbor Airport data.

- Annual normal maximum temperature .... 85.1°F
- Annual normal minimum temperature .... 57.3°F
- Record high temperature ..... 122° F (06/26/90)
- Record low temperature ..... 16° F (01/07/1913)
- Normal annual precipitation .... 7.11"

**TABLE 3: DESIGN TRAFFIC DATA**

| DESCRIPTION | | SKY HARBOR BLVD. TO AIR LANE | AIR LANE TO WASHINGTON STREET | SKY HARBOR AIRPORT TO SR 153 | SR 153 TO SR 143 |
|---|---|---|---|---|---|
| DESIGN VOLUME FOR YEAR 2010 | ADT (vpd) | 19,200 NB<br>27,100 SB | 22,800 NB<br>22,800 SB | 33,000 WB<br>33,000 EB | 26,000 WB<br>26,000 WB |
| | A.M. PEAK (vph) | 1,440 NB<br>1,710 SB | 1,765 NB<br>1,485 SB | 2,680 WB<br>2,200 EB | 2,080 WB<br>1,635 EB |
| | P.M. PEAK (vph) | 1,245 NB<br>2,140 SB | 1,485 NB<br>1,765 SB | 2,200 WB<br>2,680 EB | 1,635 WB<br>2,080 EB |
| PEAK HOUR FACTOR | | 0.9 | 0.9 | 0.95 | 0.95 |
| DESIGN SPEED (MPH) | | 50 | 50 | 30 | 40 |
| LANE CONFIGURATION | | 3 NB<br>3 SB | 3 NB<br>3 SB | 3 WB<br>3 EB | 3 WB<br>3 EB |

Notes: Air Lane is on the north west side of the project
Sky Harbor Airport is on the west end of Sky Harbor Boulevard
SR. 143 is on east end of Sky Harbor Boulevard
Washington Street is a cross street where SR. 153 and 44th street adjoin

## Site Geology

The soil profiles obtained for foundation and structural design showed[3] that the top 4 feet of soil typically consisted mainly of sand, gravel and cobbles (GP, GW, GP-GM, GW-GM). The soil was characterized by the following features:

- Bown to gray color
- Stratified soil
- Dense to very dense
- Angular to sub angular sand
- Low to medium plasticity clay fines
- Round to subrounded gravel and cobbles
- Occasional boulders

## Installation and Inspection Procedure

Each CAT system, as installed in this project, consisted of a transition subsystem to a barrier wall and the CAT subsystem. The length of the transition was 26 ft 8.75 in and the length of the CAT subsystem was 31 ft 3 in. Therefore, the overall length of the CAT system was 57 ft 11.75 in. The plan, elevation and section details of the CAT system are shown in Appendix E. The installation instructions as supplied by Syro Steel Company are given in Appendix F. Briefly, and with reference to Figure 1, the installation procedure involved the following main steps:

1. Install the appropriate transition or tail end.
2. Determine and mark location of the CAT posts.
3. Assemble foundation tubes to wood posts, and bolt soil plates to foundation tubes.

4. Sink foundation tubes and posts in the earth at marked locations.
5. Install the channel strut between posts #1 and #2.
6. Attach one end of 10-gauge slotted rails to the tail end rails extending beyond post #6.
7. Attach, as specified, the other end of the 10-gauge slotted rails to post #4.
8. Bolt one end of the 12-gauge slotted rails to the 10-gauge slotted rails at post #4.
9. Attach the other end of the 12-gauge slotted rails to post #2.
10. Install spacer channel between the rails just downstream of post #2 and bolt the whole attachment at post #2.
11. Install the cable anchor between posts #1 and #2.
12. Install the nose plates and the nose piece.
13. Check alignment and profile of the guardrail.
14. Install buckling restraint rods in both the 10-gage and 12-gage slotted rails.

The CAT systems were installed by Five G Inc. of Phoenix, Arizona. The installation was done in accordance with the installation manual supplied by Syro Steel Company. Five G Inc. reported that difficult soil conditions (extremely rocky) precluded the driving of soil foundation tubes. Instead, the CAT posts and foundation tubes were placed in drilled holes. Figures 3 through 7 show pictures of the five Crash Cushion Attenuating Terminals. Syro Steel Company inspected the systems and reported that each CAT had been thoroughly inspected and that all points of the installation checklist had been satisfied. Copies of the inspection report and inspection checklist are given in Appendices G and H, respectively.

## CONCLUSION AND RECOMMENDATIONS

On the basis of the installation and inspection procedures that were followed, it is believed that all CAT systems were installed according to the manufacturer's specifications. It is recommended that the CAT system evaluation process proceed as planned. Local maintenance personnel were requested to conduct monthly inspections of the systems (see inspection form in Appendix I), and to inform the research staff of any reported accidents that involve the systems. In order to obtain a better estimate of the initial cost of the CAT system, it is recommended that future CAT systems be included in the initial design document as bid items instead of as change-order items as was the case in this project.

**Figure 3: Crash Cushion Attenuating Terminal #1 at Station 35+10 on Sky Harbor Boulevard (West Bound Direction)**

**Figure 4: Crash Cushion Attenuating Terminal #2 at Station 24+51 on Sky Harbor Boulevard (East Bound Direction)**


**Figure 5: Crash Cushion Attenuating Terminal #3 at Station 11+70 on Ramp EN**

**Figure 6: Crash Cushion Attenuating Terminal #4 at Station 20+31 on Ramp EN**

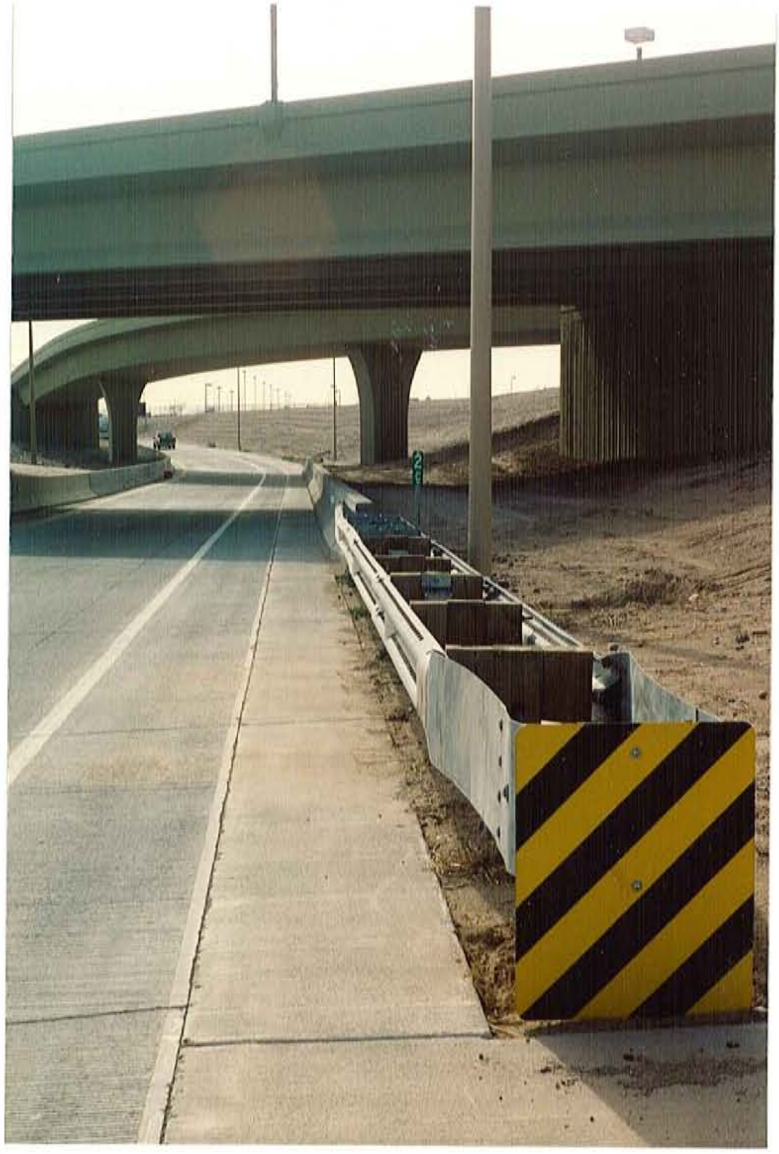


**Figure 7: Crash Cushion Attenuating Terminal #5 at Station 47+04 on Ramp SW**

## REFERENCES


1. Rollins, Greg and Scofield, Larry A., "SENTRE and TREND Attenuating Systems", Arizona Department of Transportation , FHWA-AZ-8808 & FHWA-AZ-8803, Final Report, 1991

2. Michie, Jarvis D., "Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances." NCHRP Report 230 (March 1981).

3. Plan and Profile of Proposed Phoenix Sky Harbor Urbanized Area, Sky Harbor Access Road (SR 153), RAM-601-0-501. Arizona Department of Transportation, July, 1990.

# APPENDIXES

## APPENDIX A

## LETTER FROM FHWA TO SYRO STEEL COMPANY ABOUT CLASSIFICATION OF THE CRASH CUSHION ATTENUATING TERMINAL AS AN OPERATIONAL BARRIER

U. S. Department
of Transportation

Federal Highway
Administration

REFER TO:
HNG-14

Mr. David R. Lewis
Vice President, Sales
Syro Steel Company
1170 North State Street
Girard, Ohio 44420

Dear Mr. Lewis:

My April 2 response to your request for operational status for the C. A. T. requested additional information on three separate issues. This information was provided in your April 11, 1990, response.

Briefly, you said that the recommended transition design is an adaptation of one recommended by the Federal Highway Administration (FHWA) for use in bridge approaches and that there are no indications from actual crashes that there is a snagging or pocketing problem with this design. Use of an 8x8-inch post at post 7 in advance of the reduced post spacing between post 8 and post 9 does provide some gradual stiffening. However, since the W-beam to thrie-beam transition piece that was tested by the FHWA was 12 gauge steel, and your suggested design specifies a 10 gauge piece, we believe an additional 8x8-inch post should be added between posts 7 and 8. Even if a 12 gauge transition piece is used, the extra post should be retained since the original bridge approach transition was not tested upstream from the transition piece.

The second issue raised was the performance of the C. A. T. under low temperature conditions, where brittle failure of the telescoping W-beams would, if experienced, adversely effect the units' energy-absorbing capabilities. Your Charpy test results showed, for the steel tested, that a transition from ductile to brittle failure did not occur between 60 degrees above zero and minus 10 degrees below zero. If the steel used in the manufacture of the slotted beams always exhibits this property, we conclude brittle failure should not be a problem within the test temperature range. However, this characteristic should be monitored to ensure that it persists on future production runs of M-180 steel used to produce the slotted rails for the C. A. T.

The final concern was the possibility that the relatively long section of unsupported slotted 10 gauge rail between post 4 and post 7 might have a tendency to buckle and that the system would behave more predictably if the rail were attached to post 6. Your proposed addition of a back-up plate at post 7 for a steel post system and the use of flat plate washers for both wood post and steel post systems to prevent the rail form disengaging from the blockout upon impact appears to be an acceptable design change to meet our concerns over potential unpredictable performance. Since the rail did sometimes pull over the bolt heads at post 7 in both test and field crashes, it appears that the addition of washers would be a beneficial retrofit. We recommend that existing installations be so retrofitted. We also strongly suggest that field installations be monitored to see if the washer addition at post 7 is sufficient to ensure effective performance of the 10 gauge slotted rail or if a more positive attachment is needed.

Since half the documented accident reports have come from one State and that State has some concerns over the current design, we believe it is essential to complete all current evaluations to obtain as much performance data as possible. Several other State highway agencies are currently evaluating C. A. T. units under FHWA's Experimental Projects Program. Many of these units are scheduled for installation during the summer of 1990. This increased exposure should provide additional performance data and more clearly show whether or not further modifications are necessary. However, based on our analysis of data currently available, and the revisions you have made based on preliminary results, the FHWA finds the modified C. A. T. acceptable for use as an operational terminal on Federal-aid highway projects if a State highway agency proposes its use. Since it is a proprietary item, it must be purchased or obtained though competitive bidding against equally suitable alternatives. We will also accept a limited number of additional experimental installations of the C. A. T. by State highway agencies which have not yet used it or which want additional performance data before permitting its general use.

By copy of this letter, we are advising our field offices of the new status of the C. A. T. and of the need to evaluate carefully and report the impact performance of units currently in place as well as new experimental installations. Copies of your revised drawings, and your new installation manual which were included with you May 25th letter to Mr. Richard Powers of my staff are also being forwarded to the field. It remains your responsibility to advise current users of the C. A. T. of the modifications described above as well as any others that may result from the continuing evaluation efforts of individual States.

Sincerely yours,

(signed)
L. A. Staron
Chief, Federal-Aid and Design Division

# APPENDIX B

# APPROVED WORK PLAN FOR IN SERVICE PERFORMANCE EVALUATION OF CRASH CUSHION ATTENUATING TERMINAL

## CAT CRASH CUSHION ATTENUATING TERMINAL

WORKPLAN

1. *Evaluate and document the site selection criteria, and design conditions.* This will include expected service requirements of the project and anticipated service life of the device. The geometric alignment, device location, traffic volume, vehicle operating speeds and mix, environmental conditions, and soil stratigraphy will be documented.

2. *Assign reporting procedures and responsibilities.* The ATRC will develop field evaluation forms for use by ADOT construction and maintenance personnel and DPS officers. The frequency and content of reporting will be established by the ATRC in conjunction with the participating personnel.

3. *Monitor and document the construction of the devices.* The as-built condition of each device and roadway condition will be documented. Field construction/contractor personnel will be interviewed for suggested design/procedural changes and /or improvements.

4 *Prepare a construction report documenting the design and construction of the devices.* A construction report will be prepared in accordance with ATRC procedures for reporting of experimental projects and submitted to the FHWA within 120 days after construction of the last device.

5. *Monitor in-service performance.*

    * The in-service evaluation will be conducted for 2 years.

    * Monthly field inspections will be performed by ADOT maintenance forces to record "brush hits" and drive away collisions, damage to the appurtenance, required repairs, routine maintenance, and evidence of near misses. The availability of replacement parts, level of technical support by the supplier, and total down time of the appurtenance will be documented. Unique problems such as vandalism or corrosion will be identified.

    * Reported accidents will be investigated by the ATRC as required. Damage to appurtenances will be documented and video taped. Accident reporting will be performed using techniques of the National Accident Sampling System or other acceptable procedures.

    * Traffic volume and mix will be obtained annually.

    * ATRC will perform scheduled inspections of the installation at 6 months, 1 year, and 2 years after construction. Interviews with maintenance personnel and DPS officers will be performed semiannually.

    * Annual maintenance costs will be collected by the ATRC.

6. *Evaluate in-service performance.* A before and after evaluation will be performed which evaluates the relative effectiveness of the appurtenances. Specific appurtenance performance will be evaluated on the basis of three factors: structural adequacy, occupant risk, and vehicle trajectory after collision. The evaluation criteria are as follows:

a) Structural adequacy relates to geometrical, structural and dynamic properties of an appurtenance to interact with a selected range of vehicle sizes and impact conditions in a predictable and acceptable manner. Non-vehicle collision - type forces such as wind are not included. Criteria:

Acceptable redirection of vehicle.

Controlled penetration of vehicle.

Controlled stopping of a selected range of vehicle sizes impacting the installation at specified conditions.

Detached elements, fragments, or other debris should not penetrate or show potential for penetrating the passenger compartment, or present undue hazard to other traffic.

b) Occupant Risk: Vehicle responses of acceleration and velocity changes. Criteria:

Vehicle remains upright during and after collision although moderate roll, pitching, and yawing are acceptable.

c) Vehicle Trajectory: Criteria:

Vehicle trajectory and final stopping position should intrude a minimum distance, if at all, into adjacent or opposing traffic.

The evaluation will determine if the design goals were achieved, identify special problems that affected appurtenance performance, examine impact the devices exhibited on other highway conditions, and document the initial cost and annualized maintenance cost.

7. *Prepare a final report.* A final report detailing the efforts of this study and the conclusions and recommendations will be prepared. The report will be prepared within 90 days of the completion of the final evaluation in accordance with ATRC procedures for reporting experimental projects.

# APPENDIX C

# MEMO FROM ADOT TO FHWA REQUESTING APPROVAL TO WORKPLAN FOR INSERVICE PERFORMANCE EVALATION OF CRASH CUSHION TERMINAL

ARIZONA DEPARTMENT OF TRANSPORTATION

# OFFICE MEMO

ARIZONA TRANSPORTATION RESEARCH CENTER
March 2, 1992

TO: DENNIS MITTELSTEDT
FHWA

ATTN: BILL VACHON

FROM: LARRY A. SCOFIELD
Manager - Transportation Research

SUBJECT: WORKPLAN FOR CAT CRASH CUSHION ATTENUATING TERMINAL

Submitted for your retroactive approval is the proposed Experimental Project workplan for the CAT Crash Cushion Attenuating Terminal. The terminal is being implemented at five locations along the Phoenix Sky Harbor Access Road (SR 153). Site construction is currently underway. If further action is necessary, please advise.

Sylvester A. Kalevela

for Larry A. Scofield
Manager - Transportation Research

SAK/sak
Encl.

# APPENDIX D

# WORK PLAN APPROVAL MEMO FROM FHWA TO ADOT FOR IN-SERVICE PERFORMANCE EVALUATION OF CRASH CUSHION ATTENUATING TERMINAL

May 5, 1992

HPR-AZ
(731.2)

Mr. Harry Reed
Division Director
Transportation Planning Division
Arizona Dept. of Transportation
Phoenix, Arizona 85007

Dear Mr. Reed:

The experimental workplan for the Cat Crash Cushion Attenuating Terminal as transmitted by Mr. Larry Scofield's memo of March 2, 1992, is approved.

Sincerely yours,

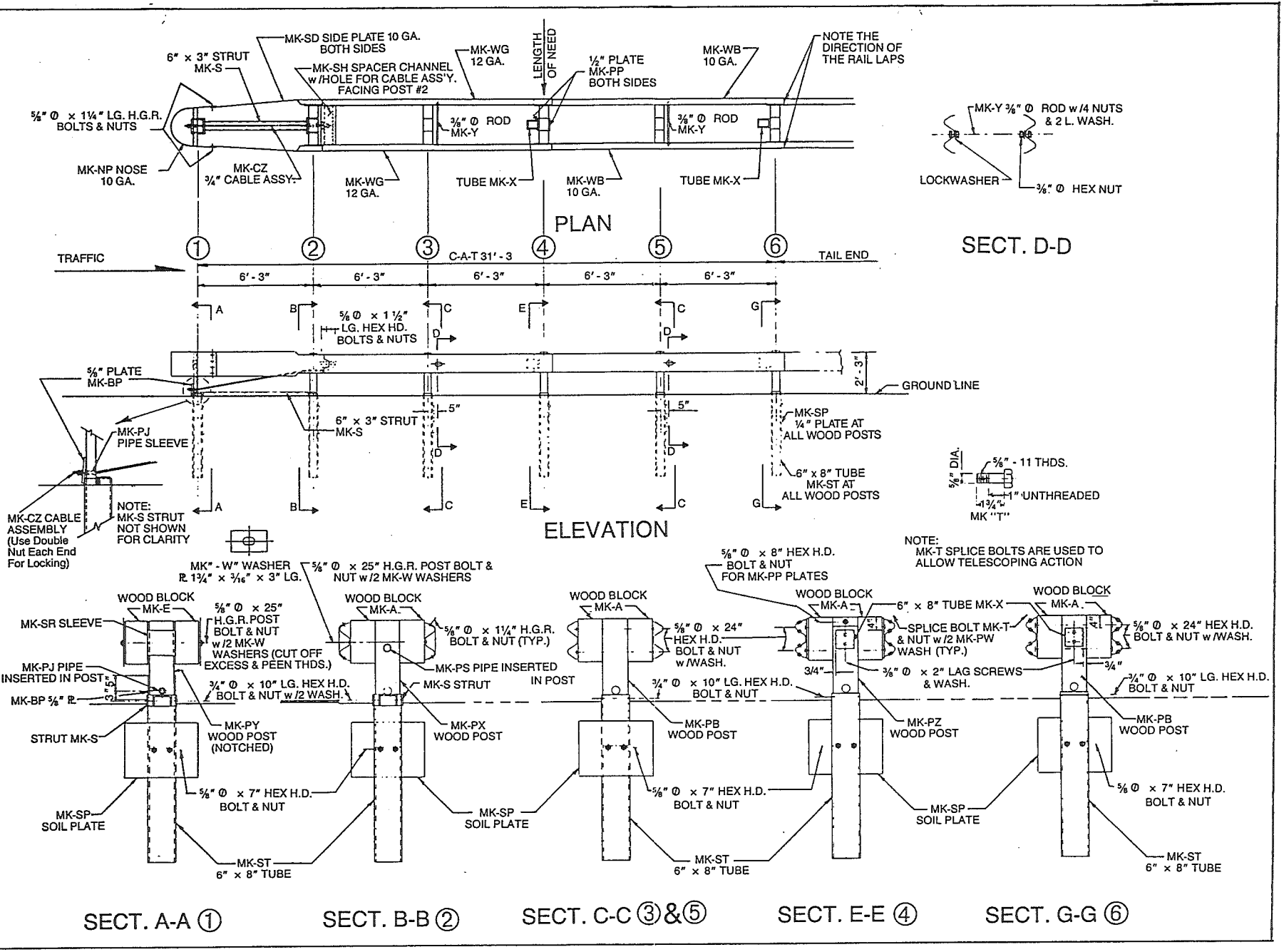
William P. Vachon

E. A. Wueste
Division Administrator

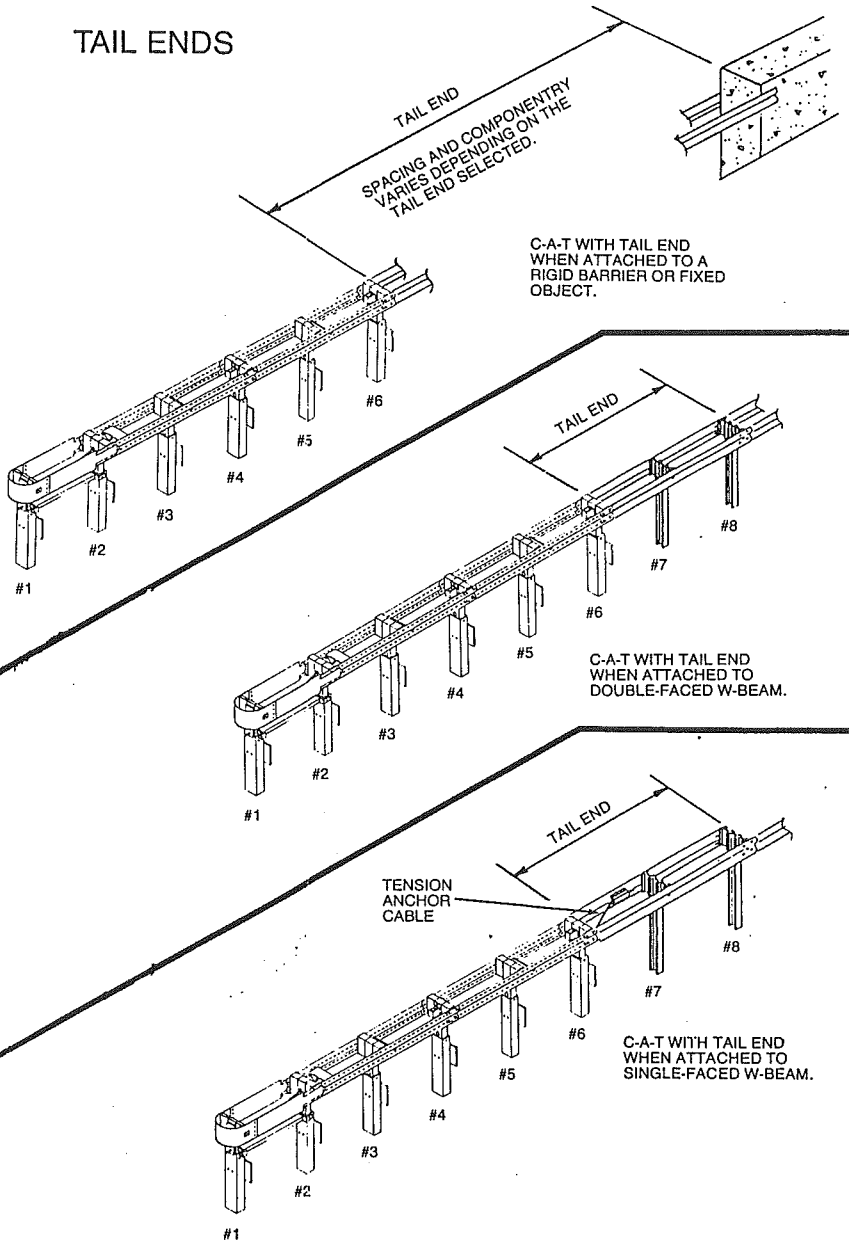
cc: L. Scofield-075R

# APPENDIX E

# CRASH CUSHION ATTENUATING TERMINAL PLAN, ELEVATION AND SECTIONS


6" x 3" STRUT MK-S
MK-SD SIDE PLATE 10 GA. BOTH SIDES
MK-SH SPACER CHANNEL w/HOLE FOR CABLE ASS'Y. FACING POST #2
MK-WG 12 GA.
LENGTH OF NEED
½" PLATE MK-PP BOTH SIDES
MK-WB 10 GA.
NOTE THE DIRECTION OF THE RAIL LAPS
⅝" Ø x 1¼" LG. H.G.R. BOLTS & NUTS
⅜" Ø ROD MK-Y
MK-NP NOSE 10 GA.
MK-CZ ¾" CABLE ASSY.
MK-WG 12 GA.
TUBE MK-X
MK-WB 10 GA.
TUBE MK-X
PLAN
MK-Y ⅜" Ø ROD w/4 NUTS & 2 L. WASH.
LOCKWASHER
⅜" Ø HEX NUT
SECT. D-D
TRAFFIC
C-A-T 31' - 3
TAIL END
6' - 3"
⅝ Ø x 1 ½" LG. HEX HD. BOLTS & NUTS
⅝" PLATE MK-BP
2' - 3"
GROUND LINE
MK-PJ PIPE SLEEVE
6" x 3" STRUT MK-S
5"
MK-SP ¼" PLATE AT ALL WOOD POSTS
6" x 8" TUBE MK-ST AT ALL WOOD POSTS
MK-CZ CABLE ASSEMBLY (Use Double Nut Each End For Locking)
NOTE: MK-S STRUT NOT SHOWN FOR CLARITY
ELEVATION
⅝" DIA.
⅝" - 11 THDS.
1" UNTHREADED
1¾"
MK "T"
MK" - W" WASHER 1¾" x 3/16" x 3" LG.
⅝" Ø x 25" H.G.R. POST BOLT & NUT w/2 MK-W WASHERS
⅝" Ø x 8" HEX H.D. BOLT & NUT FOR MK-PP PLATES
NOTE: MK-T SPLICE BOLTS ARE USED TO ALLOW TELESCOPING ACTION
WOOD BLOCK MK-E
WOOD BLOCK MK-A
WOOD BLOCK MK-A
WOOD BLOCK MK-A
WOOD BLOCK MK-A
6" x 8" TUBE MK-X
MK-SR SLEEVE
⅝" Ø x 25" H.G.R. POST BOLT & NUT w/2 MK-W WASHERS (CUT OFF EXCESS & PEEN THDS.)
⅝" Ø x 1¼" H.G.R. BOLT & NUT (TYP.)
⅝" Ø x 24" HEX H.D. BOLT & NUT w/WASH.
SPLICE BOLT MK-T & NUT w/2 MK-PW WASH (TYP.)
⅝" Ø x 24" HEX H.D. BOLT & NUT w/WASH.
MK-PJ PIPE INSERTED IN POST
MK-PS PIPE INSERTED IN POST
MK-S STRUT
¾" Ø x 10" LG. HEX H.D. BOLT & NUT w/2 WASH
¾" Ø x 10" LG. HEX H.D. BOLT & NUT
⅜" Ø x 2" LAG SCREWS & WASH.
¾" Ø x 10" LG. HEX H.D. BOLT & NUT
MK-BP ⅝" R
STRUT MK-S
MK-PY WOOD POST (NOTCHED)
MK-PX WOOD POST
MK-PB WOOD POST
MK-PZ WOOD POST
MK-PB WOOD POST
⅝" Ø x 7" HEX H.D. BOLT & NUT
⅝" Ø x 7" HEX H.D. BOLT & NUT
⅝" Ø x 7" HEX H.D. BOLT & NUT
MK-SP SOIL PLATE
MK-SP SOIL PLATE
MK-SP SOIL PLATE
MK-ST 6" x 8" TUBE
MK-ST 6" x 8" TUBE
MK-ST 6" x 8" TUBE
SECT. A-A ①
SECT. B-B ②
SECT. C-C ③&⑤
SECT. E-E ④
SECT. G-G ⑥

# TAIL ENDS




BILL OF MATERIAL

| MK. | QTY. | DESCRIPTION |
|---|---|---|
| NP | 1 | NOSE x 10 GA. |
| SD | 2 | SIDE PLATE x 10 GA. |
| WG | 2 | DEEP BEAM x 12 GA. x 13' - 6½" |
| WB | 2 | DEEP BEAM x 10 GA. x 13' - 6½" |
| S | 1 | CHANNEL STRUT x 6' - 6" |
| ST | 6 | STEEL FOUNDATION TUBE |
| PY | 1 | WOOD POST |
| PX | 1 | WOOD POST |
| PB | 3 | WOOD POST |
| PZ | 1 | WOOD POST |
| E | 2 | WOOD BLOCK |
| A | 10 | WOOD BLOCK |
| SR | 1 | SLEEVE |
| SH | 1 | SPACER CHANNEL |
| X | 2 | STEEL TUBE |
| SP | 6 | SOIL PLATE |
| PJ | 1 | PIPE SLEEVE |
| PS | 1 | PIPE SLEEVE |
| PP | 2 | POST PLATE |
| BP | 1 | BEARING PLATE |
| CZ | 1 | CABLE ASSEMBLY |
| Y | 2 | ⅜" Ø RESTRAINT ROD |
| PW | 32 | PLATE WASHER |
| | | |
| | | HARDWARE: |
| | | |
| W | 4 | RECT. WASHER |
| T | 32 | ⅝" Ø x 1¾" LG. H.H. SPLICE BOLT |
| | 2 | ⅝" Ø 25" LG. H.G.R. BOLT |
| | 8 | ⅝" Ø x 24" LG. H.H. BOLT |
| | 1 | ⅝" Ø x 8" LG. H.H. BOLT |
| | 12 | ⅝" Ø x 7" LG. H.H. BOLT |
| | 8 | ⅝" Ø x 1½" LG. H.H. BOLT |
| | 16 | ⅝" Ø x 1¼" LG. H.G.R. BOLT |
| | 6 | ¾" Ø x 10" LG. H.H. BOLT |
| | 4 | ⅜" Ø x 2" LG. LAG SCREW |
| | 8 | ⅜" HEX NUT |
| | 4 | ⅜" LOCK WASHER |
| | 4 | ⅜" FLAT WASHER |
| | 18 | ⅝" H.G.R. NUT |
| | 61 | ⅝" HEAVY HEX NUT |
| | 8 | ⅝" FLAT WASHER |
| | 6 | ¾" HEX NUT |
| | 4 | ¾" FLAT WASHER |
| | 4 | 1" HEX NUT |
| | 2 | 1" FLAT WASHER |

C-A-T
CRASH CUSHION/ATTENUATING TERMINAL
PLAN, ELEVATION & SECTIONS

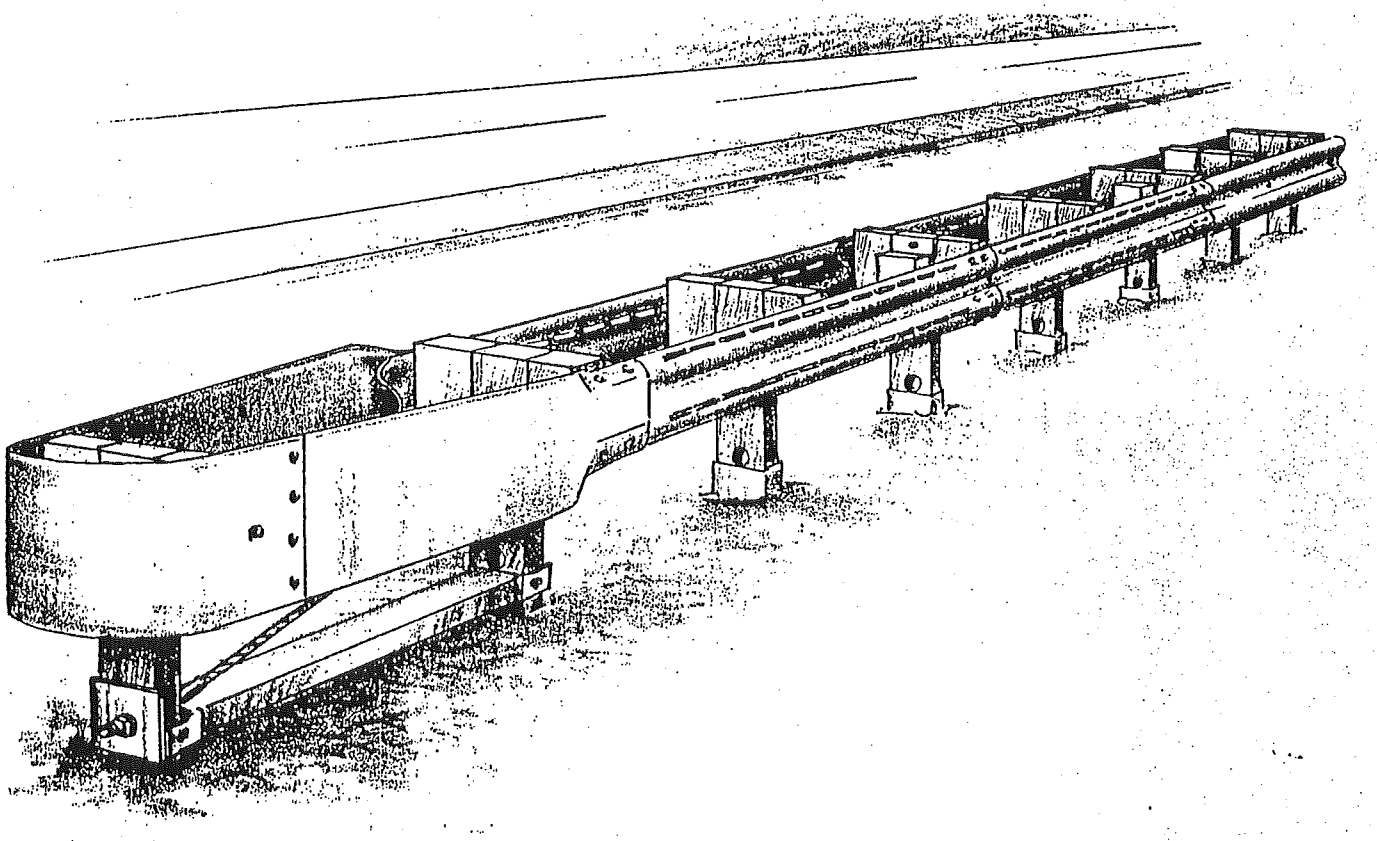
Syro Steel Company

# APPENDIX F

# CRASH CUSHION ATTENUATING TERMINAL INSTALLATION INSTRUCTIONS

CAT®

# Installation instructions for Syro Crash Cushion/ Attenuating Terminal— called C-A-T for short.




SYRO

**SYRO STEEL COMPANY**

**Girard, OH 44420**
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Fax: (216) 545-0749

**Centerville, UT 84014**
(801) 292-4461
(800) 772-7976
Fax: (801) 292-2145

# Installing C-A-T systems

## ...from Syro

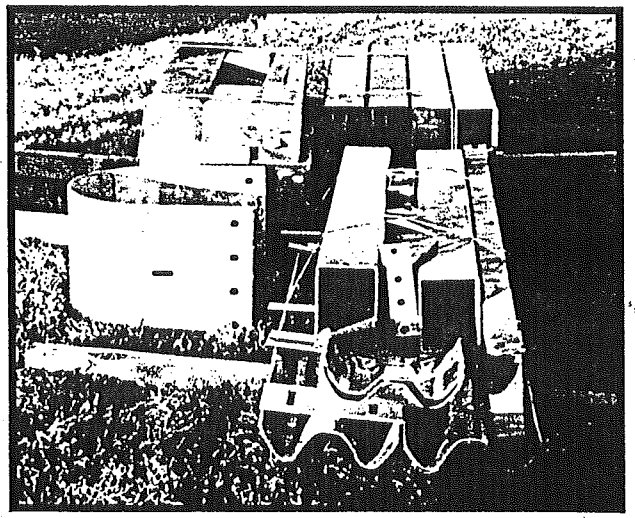
These instructions cover the installation of the Syro C-A-T system, beginning at Post #6 and working back to Post #1, which is the nose end.

### materials

As packaged, your C-A-T systems includes all material needed for its installation from Post #1 up to and including Post #6.

A tail-end section is included in a second package of material needed to attach the C-A-T to the existing barrier or fixed object. Typical tail-end attachments are shown on the inside pages alongside the erection drawing of the C-A-T system itself. A separate detailed drawing of the applicable tail-end section accompanies each shipment.

If the system is to be attached to a double- or single-faced W-beam guardrail, the tail-end stops at Post #8, where the standard highway guardrailing begins.



If it is to be attached to a rigid barrier or fixed object, the tail-end will stop at the rigid barrier or fixed object.

With each C-A-T shipment is a steel drum containing bags of attachment hardware. These bags are individually tagged showing the location of the posts where the hardware in that bag is to be used.

### tools required

Tools required are those ordinarily used to install standard guardrails. They include sockets and wrenches for 3/8", 5/8", 3/4" and 1" hex nuts and such other equipment as augers and post pounders commonly used in driving posts.

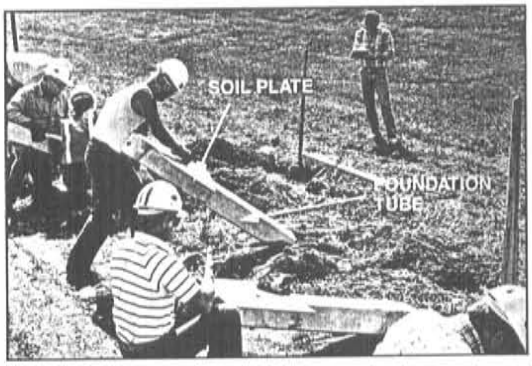
### site preparation

Site preparation requires only the layout of a line establishing post locations. The C-A-T system is installed in a straight line. No flares. No turns. Posts are spaced at 6'3" centers. Note: concrete footings or foundations are not required.

# beginning assembly

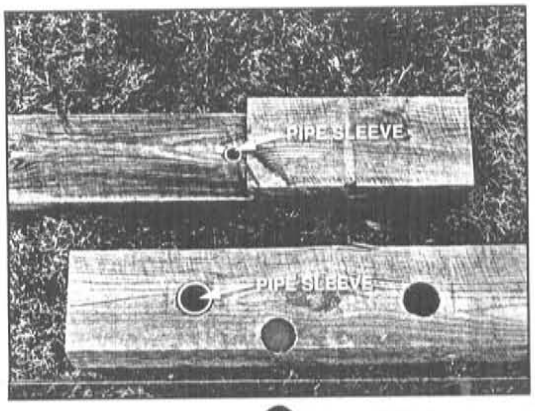
**1** Assemble foundation tubes to wood posts. Then bolt soil plates (MK-SP) to foundation tubes (MK-ST) with two 5/8" × 7" hex bolts and nuts. This occurs at six places.

Note: The soil plate is positioned on the downstream side of the post. This is the side farthest from the nose.

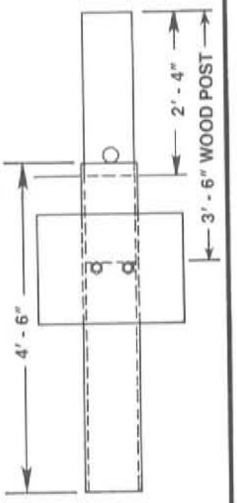



**2** Install pipe sleeve (MK-PJ) in notched wood post (MK-PY).

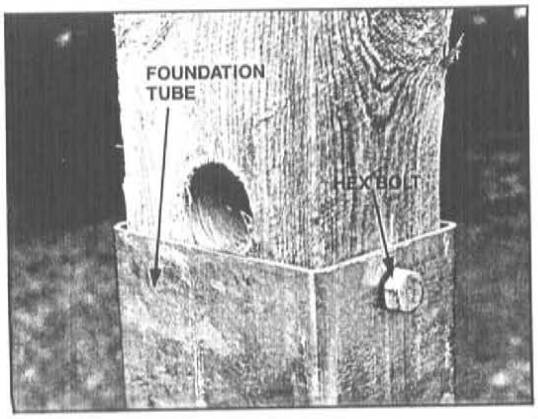
Install pipe sleeve (MK-PS) in wood post (MK-PX) near the top of the post.




**3** Next, sink the foundation tubes and posts in the earth. Depending upon soil conditions and available equipment, you may elect to loosen the soil with an auger before setting the posts. You may partially embed these steel tubes before inserting posts, or pound the tubes and posts as a single unit. Whichever method is used, the finished rail height will be 2'3", while the top of the posts will measure 2'4".

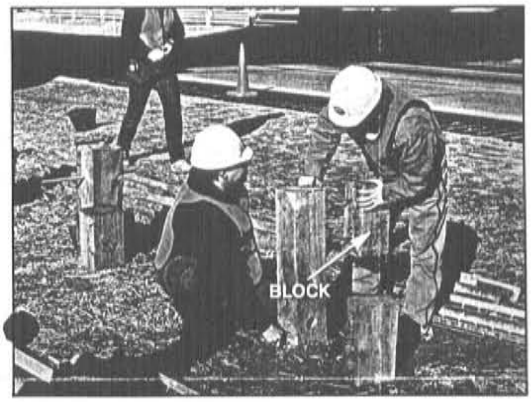



**4** A 3/4" × 10" hex bolt and nut are used to attach each wood post to its foundation tube. Two 3/4" washers are also used at Posts #1 and #2.

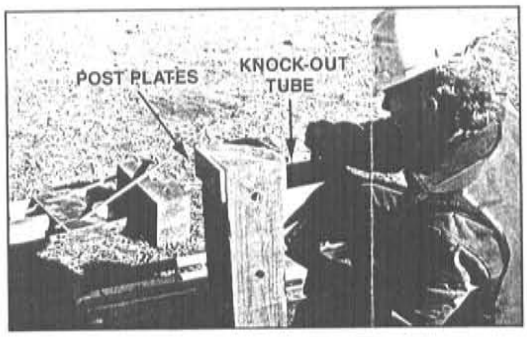


**5** Install wood post (MK-PB) at Locations #6, #5, and #3, beginning at Location #6.
Install wood post (MK-PZ) at Location #4.
Install wood post (MK-PX) at Location #2.
Install notched wood post (MK-PY) at Location #1. The notched side faces Post #2.


**6** Because there is no rail-to-post attachments at Locations #3, #5 and #6, attach wood blockouts (MK-A) at these locations, using two 5/8" × 24" hex bolts, nuts and washers.




**7** Attach knockout tube (MK-X) to the upstream side of Posts #6 and #4 with two 3/8" × 2" lag screws and flat washers. The tube is positioned 4" from the top of the post.
Attach post plates (MK-PP) to the top of Post #4 with a 5/8" × 8" hex bolt and nut.

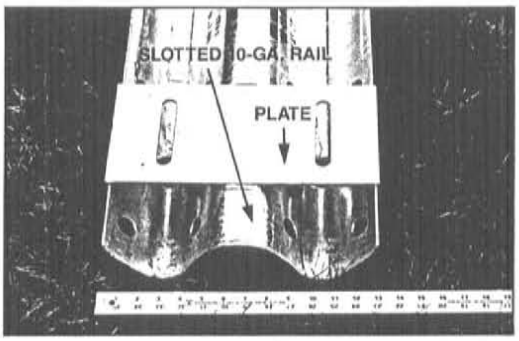



**8** Hook the slotted yokes of the channel strut (MK-S) over the 3/4" bolts at the base of Posts #1 and #2. Either end of the channel can be placed at Post #1. The 3/4" flat washers facilitate these connections.

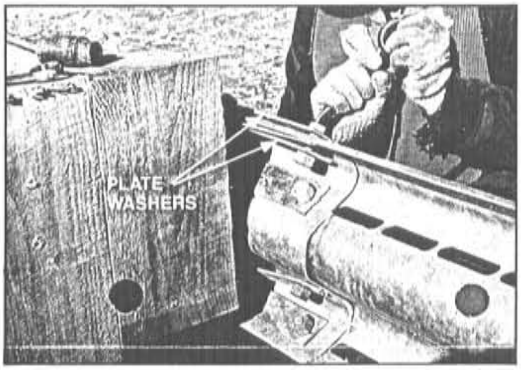
## begin hanging rails

**9** At this point the posts and guardrail downstream from Post #6 should be in place. This is the "tail end" mentioned earlier.

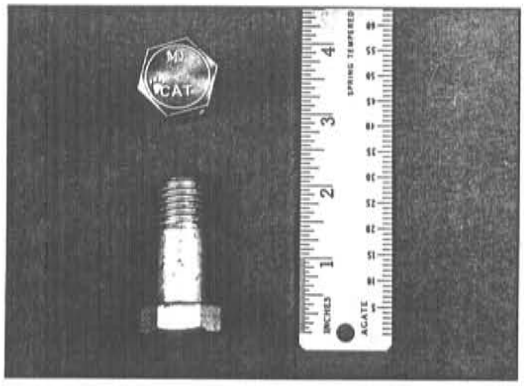
Now start with the two 10-gage rails (MK-WB) that span from Post #4 to #6. These are the slotted rails with plates welded to the back side on one end. The welded plates are positioned at Post #4.



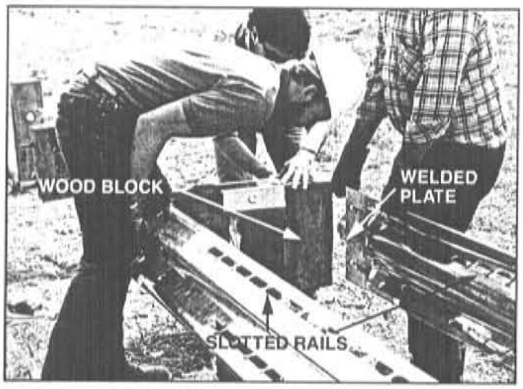

**10** Each of these rails is attached to the outside of the rail extending beyond Post #6. Each splice at Post #6 is made with eight (8) plate washers (MK-PW) and eight (8) 5/8" × 1¾" hex head bolts (MK-T) and nuts.




**11** This bolt has a portion of its shank purposely unthreaded. For functional reasons, do not substitute with ordinary bolts at risk of changing the design concept. Proper bolts are identified by the C-A-T symbol.

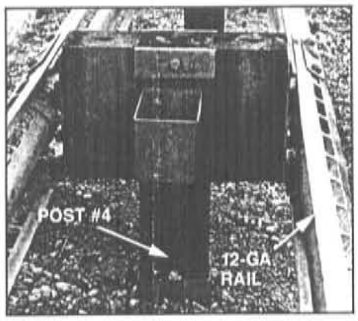



**12** Attach the welded plates of the 10-gage slotted rails, along with two wood blocks (MK-A), to Post #4. Secure this attachment with two 5/8" × 24" hex bolts, nuts and washers.



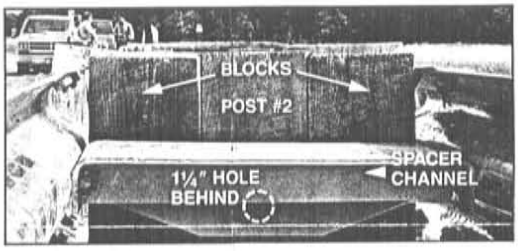
**13** The two 12-gage slotted rails (MK-WG) are positioned with the 8¼"-long slots at Post #4. The four ¾" diameter holes are at the Post #2 end.

These slotted rails (MK-WG) are now bolted to the outside of the slotted rails (MK-WB) at Post #4. Again, eight (8) plate washers (MK-PW) and eight (8) ⅝" x 1¾" hex head bolts (MK-T) and nuts are used to make the connection.

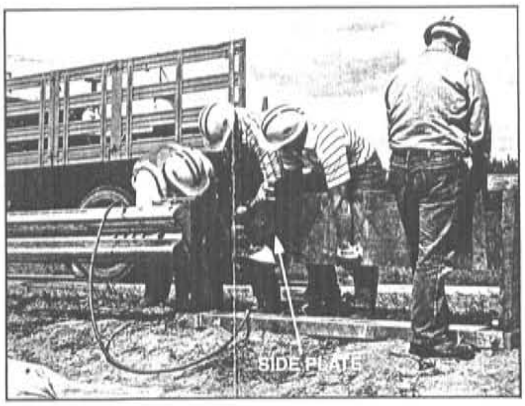



**14** Before tightening the rails and blocks to Post #2, install the spacer channel (MK-SH) between the rails just downstream from Post #2. Locate the spacer channel with the 1¼" diameter hole facing Post #2. Now attach spacer channel to rails with eight (8) ⅝" x 1½" hex bolts and nuts.

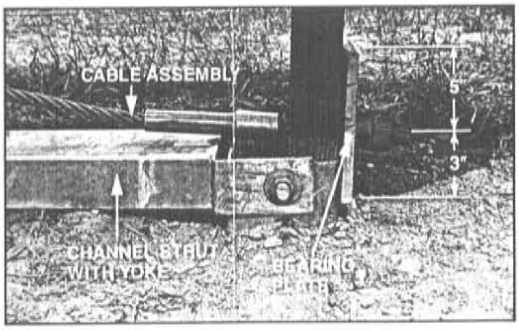
Then make the attachment at Post #2 next with two wood blocks (MK-A), using a ⅝" x 25" highway guardrail bolt, two (2) rectangular washers (MK-W) and a guardrail nut.



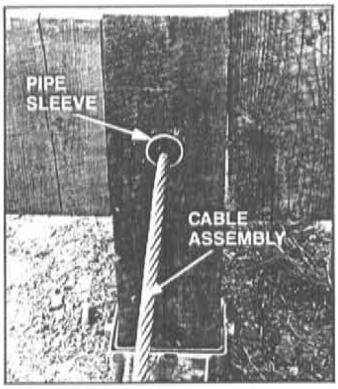

**15** Bolt the side plates (MK-SD) to the end of each 12-gage slotted rail, using four (4) ⅝" x 1¼" standard highway guardrail bolts and nuts.



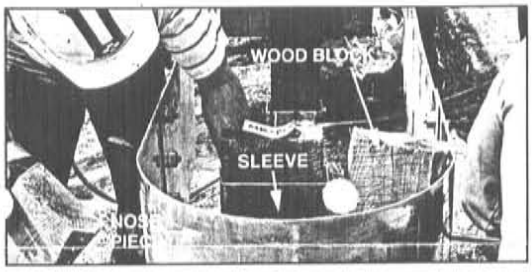

**16** Installation of the cable assembly (MK-CZ) follows. Place one end through the pipe sleeve at the base of Post #1. Place the bearing plate (MK-BP) over the cable stud, being sure the 5" edge dimension is above the stud. Secure it with a 1" hex nut and washer.



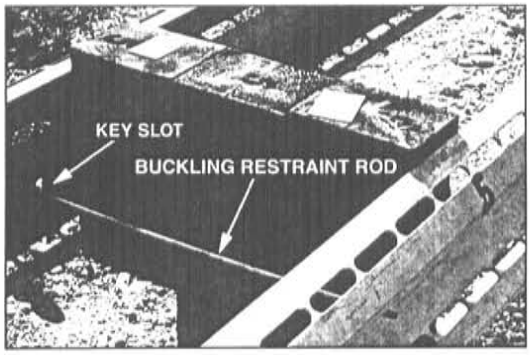
**17** Place the opposite end through the pipe sleeve at the top of Post #2, then through the 1¼" diameter hole in the spacer channel. Secure this end with a 1" hex nut and washer. A second 1" nut is added to each end of the cable assembly to prevent loosening.



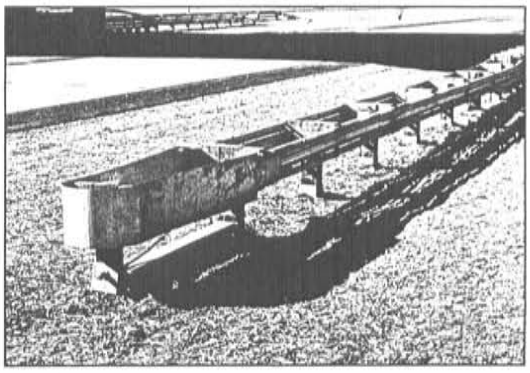

**18** Bolt the nose piece (MK-NP) to the side plates, using eight (8) standard ⅝" × 1¼" highway guardrail bolts and nuts. Place the sleeve (MK-SR) over Post #1 and attach narrow wood blocks (MK-E) while fastening the nose. A ⅝" × 25" highway guardrail post bolt, two (2) rectangular washers (MK-W) and a guardrail nut are used in making this attachment. Be sure to cut off and peen excess threads.




**19** After checking alignment of the guardrail and the rail height, install the buckling restraint rods (MK-Y) through the opposing keyhole slots in both the 10-gage and 12-gage slotted rails. This ⅜" × 24½" long rod requires a lockwasher and a double nut attachment at each end.




***Inspect assembly to ensure all parts are located in proper position. Your C-A-T system is now complete, ready to enter service.***



**SYRO STEEL COMPANY**

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# APPENDIX G

## CRASH CUSHION ATTENUATING TERMINAL INSPECTION REPORT FROM SYRO STEEL COMPANY

STEEL COMPANY WESTERN DIVISION PO BOX 99 CENTERVILLE, UTAH 84014 TELEPHONE (801) 292-4461 FAX 801-292-2145 HOME OFFICE: BIRARD, OHIO

SYRO

March 19, 1992

Mr. John Gray
5 G
3801 E. Superior
Phoenix, AZ 85040

Dear John:

After the inspection by our representative, Randy Olsen, we feel that the C.A.T. systems you have installed should be considered fully operational. Each C.A.T. has been thoroughly inspected, and all points of our checklist have been satisfied.

Your installation expertise is second to none, and we thank you for using our safety products.

Sincerely,

G. Judd Jackson
Sales Manager - Highway Products

GJJ:rj

# APPENDIX H

## CRASH CUSHION ATTENUATING TERMINAL INSPECTION CHECK LIST

# INSPECTION CHECKLIST

STATE: DATE:

UNIT IDENTIFICATION & LOCATION:

FUNCTION:

☐ CRASH CUSHION ☐ MEDIAN TERMINAL ☐ SHOULDER TERMINAL

MATERIAL SUBSTITUTIONS:

☐ AWARE OF NONE ☐ CLEARED WITH SYRO STEEL

☐ PROPER AND UNIFORM RAIL HEIGHT.

☐ BREAKAWAY HOLE IN ALL 6 WOOD POSTS.

☐ WEAKENED POST #1 ATTACHMENT TO NOSE COMPLETE WITH SLEEVE, NARROW BLOCKS AND WASHERS.

☐ POST BOLT #1 HAS BEEN ADJUSTED FOR LENGTH AND NUT LOCKED.

☐ PROPER ORIENTATION OF BEARING PLATE.

☐ SOIL PLATES VERIFIED WITH FOUNDATION TUBES.

☐ ANCHOR CABLE PROPERLY INSTALLED AND PIPE SLEEVES INSERTED INTO POSTS #1 AND #2.

☐ STRUT CHANNEL PROPERLY ATTACHED.

☐ SPACER CHANNEL PROPERLY ATTACHED.

☐ GUARDRAILS SPANNING FROM POSTS #2 TO #4 ARE 12 GAGE MK-WG AND ARE POSITIONED WITH THE 8 1/4" LONG SLOT AT POST #4.

☐ NO RAIL ATTACHMENT AT POST #3 BUT A RESTRAINT ROD ATTACHED JUST DOWNSTREAM.

☐ RAIL SPLICES AT POST #4 PERMIT TELESCOPING.

☐ RAIL SPLICES AT POST #4 INCLUDE PLATE WASHERS AND MK-T SPECIAL SPLICE BOLTS.

☐ POST PLATES AND KNOCKOUT TUBE IN PLACE AT POST #4.

☐ GUARDRAILS SPANNING FROM POSTS #4 TO #6 ARE 10 GAGE MK-WB AND ARE POSITIONED WITH THE WELDED ATTACHMENT PLATES AT POST #4.

☐ NO RAIL ATTACHMENT AT POST #5 BUT A RESTRAINT ROD ATTACHED JUST DOWNSTREAM.

☐ RAIL SPLICES AT POST #6 PERMIT TELESCOPING.

☐ RAIL SPLICES AT POST #6 INCLUDE PLATE WASHERS AND MK-T SPECIAL SPLICE BOLTS.

☐ NO RAIL ATTACHMENT AT POST #6 BUT THE KNOCKOUT TUBE IS IN PLACE.

☐ TAIL END AND/OR TRANSITION AS REQUIRED HAVE BEEN INSTALLED IN ACCORDANCE WITH CONTRACT PLANS.

- CONNECTION TO A FIXED OBJECT REQUIRES A STIFFNESS TRANSITION.
- CONNECTION TO MEDIAN GUARDRAIL REQUIRES ONLY 12'-6" LONG TAIL END.
- CONNECTION TO SHOULDER GUARDRAIL REQUIRES A 12'-6" LONG TAIL END WITH A BACKSIDE CABLE ANCHOR AT THE DISCONTINUOUS GUARDRAIL AT POST #8.

ADDITIONAL NOTES:

INSPECTION PERFORMED BY: _____

# APPENDIX I: FORM FOR FIELD INSPECTION REPORT

ARIZONA TRANSPORTATION RESEARCH CENTER

# FIELD INSPECTION REPORT

IN-SERVICE PERFORMANCE OF THE CRASH CUSHION ATTENUATING TERMINAL (CAT)

**INSTRUCTIONS:** Personnel from the local maintenance org should make an inspection once a month. Inspection should be made in such a manner that will not endanger the passing motorists and the inspecting personnel. **[A]** Monthly field inspections: (i) Record "brush hits" and drive away collisions, damage to the appurtenance, required repairs, routine maintenance, and evidence of near misses; (ii) Document the availability of replacement parts, level of technical support by the supplier, and total down time of the appurtenance; and (iii) Identify unique problems such as vandalism or corrosion. **[B] Reported accidents:** Document and video tape damage to appurtenances. Inform the ATRC project engineer (831-2620) immediately and before any repairs are made. **[C]** Send copy of report to Arizona Transportation Research Center, Mail Drop 075R.

LOCATION _____ DATE _____

ROUTE _____ MILEPOST _____ DIRECTION _____

INSPECTED BY _____ ORG NUMBER_____

INSPECTION ITEM LIST

| | **Description** | **Yes** | **No** | **Remarks** (use additional paper if necessary) |
|---|---|---|---|---|
| 1 | Brush hit | | | |
| 2 | Drive away collision | | | |
| 3 | System has been vandalized | | | |
| 4 | Evidence of near miss | | | |
| 5 | Corrosion | | | |
| 6 | Vehicle induced Damage | | | |
| 7 | DPS report | | | |
| 8 | Initial impact at nose | | | |
| 9 | Total length damaged _____ feet | | | |
| 10 | Repairs required/performed | | | |
| 11 | Traffic control required | | | |
| 12 | Replacement parts needed | | | |
| 13 | Problems with getting parts? | | | |
| 14 | How long to receive parts ____ weeks | | | |
| 15 | Additional observations | | | |

**sketch and/or comments** (use additional paper if necessary)